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WADC TECHNICAL REPORT 54-236

# SPEED AND ACCURACY OF RESPONSE TO FIVE DIFFERENT ATTITUDE INDICATORS


*JOHN F. GARDNER, CAPT, USAF*

*AERO MEDICAL LABORATORY*


*DECEMBER 1954*

WRIGHT AIR DEVELOPMENT CENTER

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PROJECT No. 7189


WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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## FOREWORD

The experiments included in this report were conducted by the Psychology Branch, Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, under Research and Development Task No. 71571, "Principles of Instrument Presentation," with Captain John F. Gardner as Task Scientist.

Prior to completion of the report, Captain Gardner was assigned to overseas duty. The writing of the present report is largely the work of Captain Robert J. Lacey and Captain Charles M. Seeger.

## ABSTRACT

This study was conducted in order to (1) determine the optimal attitude indicator design from a field of five designs and (2) compare two methods of obtaining data which could be used to determine optimal attitude indicator designs. Five attitude indicators were used in the study, two were of the "earth reference" type, in which the moving element represented the horizon as on the conventional attitude indicator. Two were of the "airplane reference" type, in which the moving element represented the aircraft, and one simulated a "stabilized sphere" type of presentation.

The design situation tested subject response time and accuracy under two conditions. Condition one (1) required the subject to make a corrective manual response with a simulated control stick, to deviations as presented on the instruments. Condition two (2) required the subject to make a corrective verbal response, to deviations as presented on the instruments.

One hundred (100) subjects were used in the experiment. Fifty (50) were highly experienced Air Force instrument pilots and fifty (50) were college students who had had no training or experience in flying.

The experienced pilots performed equally well on all instruments as far as response errors were concerned. This situation held true for both parts of the experiment. For response times, one "airplane reference" type instrument showed a reliable advantage over one "earth reference" type instrument; however, this advantage existed for the verbal portion of the experiments only.

Like the experienced pilots the college students performed equally well on all instruments with respect to reversal errors. However, for response times one "airplane reference" type instrument showed a reliable advantage over one "earth reference" type instrument for both manual and verbal parts of the experiment.

The data gathered was not critical to a point which would permit an accurate statement relative to the optimal instrument design. However, this study does indicate that the present standard attitude instrument is not the optimum design.


## PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Jack Bollerud

JACK BOLLERUD, Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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# I. INTRODUCTION

This report presents the results of the second in a series of experiments designed to gather information regarding several methods of presenting attitude information. The reader is referred to WADC Technical Report No. 54-32, dated April 1954, "An Experimental Comparison of Five Different Attitude Indicators" (Gardner and Lacey, 1) for background information for the present study.

These findings are generally in agreement with prior studies by Browne (2) and Loucks (3) which demonstrated superiority of the airplane reference instrument over the standard A/H. Although the results of his study and the statistical differences were not conclusive, there was a definite tendency toward superior performance using an airplane reference instrument.

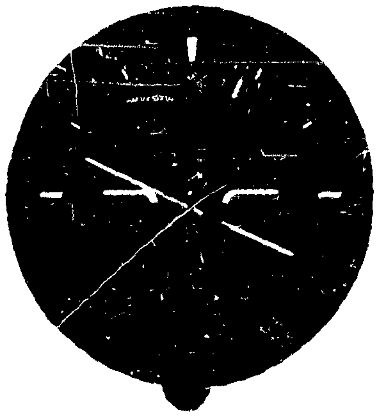
The purpose of this experiment was twofold: (1) To determine the optimal attitude indicator design from a field of five designs, using speed and accuracy of reaction of both experienced pilots and naive college students as a measure of efficiency, and (2) Comparison of two methods of obtaining data which could be used to determine the optimal attitude indicator design.

# II. APPARATUS

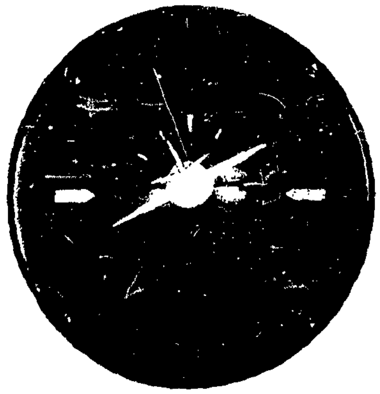
The apparatus used for this experiment consisted of five simulated attitude indicators (Figure 1), an experimental light-tight cockpit,(Figure 2), and an exposure apparatus (Figure 3).

All the attitude indicators with the exception of E, Figure 1, were designed for use in a C-8 Link Trainer. They were modified slightly for this experiment by duplicating the instrument faces and pointers on the back of the instruments so that they could be set by hand from the rear (Figure 4). Each type of attitude indicator represented some variation of three basic methods of presenting attitude information.

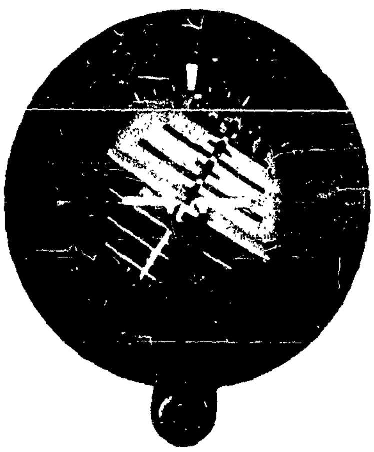
These three methods are explained in detail in the above mentioned report, WADC TR 54-32, Gardner, (1). Briefly, the various presentations are as follows: Attitude indicators typically consist of two basic elements, a movable element and a fixed element. Either of these elements may be designated as the external, fixed reference, while the other becomes the aircraft. If the movable element is designated as the aircraft, the indicator may be classed as the "airplane reference" type. If the movable element is designated as the horizon, the indicator is classed as an "earth reference" type. Instrument B in Figure 1 is an example of the "airplane reference" type. Instrument A is an example of the "earth reference" type. A third principle of indication utilizes the concept of a "stabilized sphere." This sphere is conceived as located at either the axial center of the aircraft or at some point in space ahead of the aircraft. The top and bottom halves of the sphere are of different colors. The plane of the dividing line between the two halves remains parallel to the earth's surface at all times. This principle is illustrated as Instrument D in Figure 1.



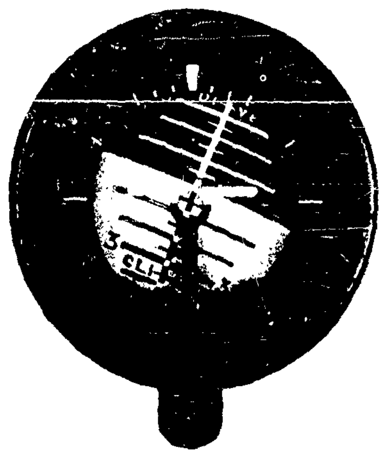
**INSTRUMENT A**
**STANDARD ARTIFICIAL HORIZON (A/H)**



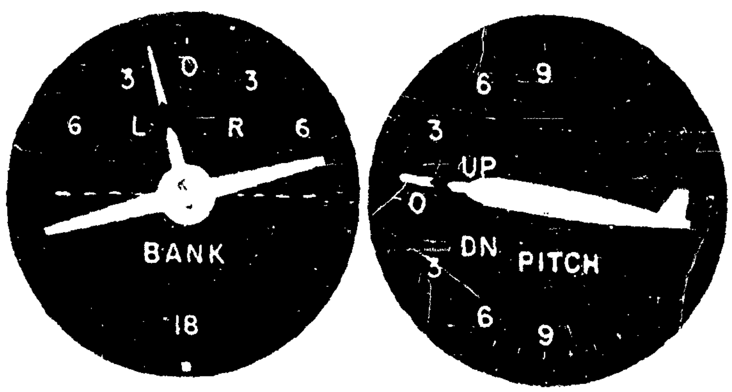
**INSTRUMENT B**
**PLANE TYPE PRESENTATION (P/T)**



**INSTRUMENT C**
**REVERSED PITCH STABILIZED SPHERE (RPS/S)**



**INSTRUMENT D**
**STABILIZED SPHERE (S/S)**




**INSTRUMENT E**
**BRITISH TYPE PRESENTATION (BR/T)**

Figure 1: Five Methods of Attitude Presentation

The three basic methods of presenting attitude information in the present study, then, are "airplane reference", "earth reference", and the "stabilized sphere". In addition to the three instruments, A, B and D of Figure 1, instruments C and E were included in the study. Instrument C is an example of the "earth reference" principle. Instrument E is a variation of the "airplane reference" instrument.

This study is divided into two parts, one using a "manual response" and the other a "verbal response". The experimental cockpit used in the manual response portion of the study was removed from an obsolete C-3 Link Trainer, Figure 2. The control stick was wired to a series of lights and two 1/100-second standard electric timers. With this arrangement, it was possible to record the time interval between the presentation of the stimulus and the completed response. A wiring diagram of the circuit is shown in Figure 5.

The slide apparatus used in the verbal response part of the study consisted of a wood frame with a slide shutter, designed to hold the experimental instruments, as shown in Figure 3. A micro switch, located at the top of the frame, actuated a timer when the slide was raised. A single on-off switch, operated by the experimenter, stopped the clock at the completion of the subject's response.

Subjects:

The subjects used for this experiment were drawn from two widely differing populations. Group A consisted of fifty pilots from the USAF Instrument School, Barksdale Air Force Base, Louisiana. This group averaged 260 hours instrument time. The majority of the subjects in this group were at the time or had been instructors at the Instrument School. The remainder of the group consisted of selected pilots attending the school.

Group B consisted of fifty subjects drawn from the student body of Antioch College, Yellow Springs, Ohio. None of these subjects had had any previous experience with the various types of attitude indicators, and very few had had any contact whatsoever with flying.

The subjects of Group A were randomly divided into ten subgroups. Each of the attitude indicators was assigned to two subgroups, a "manual first" and a "verbal first". Table 1 shows the division of subjects by groups and subgroups. Subjects of Group B were assigned to attitude indicator groups in the same manner as Group A.

Procedure:

All subjects, as they reported, were given an explanation of the purpose of the experiment and were read the instructions pertinent to their group and subgroup. The instructions are presented in Appendix I.

Each of the subjects in the "manual first" subgroup were seated in the cockpit (Figure 2). Those in the "verbal first" subgroup were each seated before the slide apparatus at a distance of 28 inches (Figure 3). Each group was given the same instructions with the exception of the explanation of the

Figure 2: Light-Tight Cockpit Used in Manual Procedure

Figure 3: Exposure Apparatus Used in Verbal Procedure

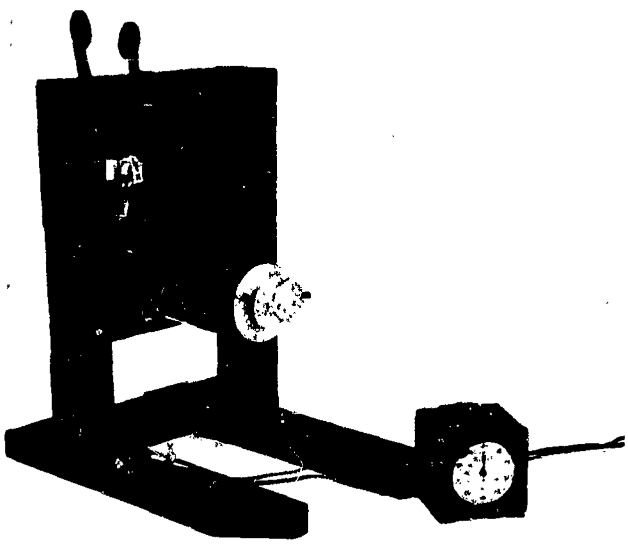


Figure 4: Rear View of Experimental Indicators

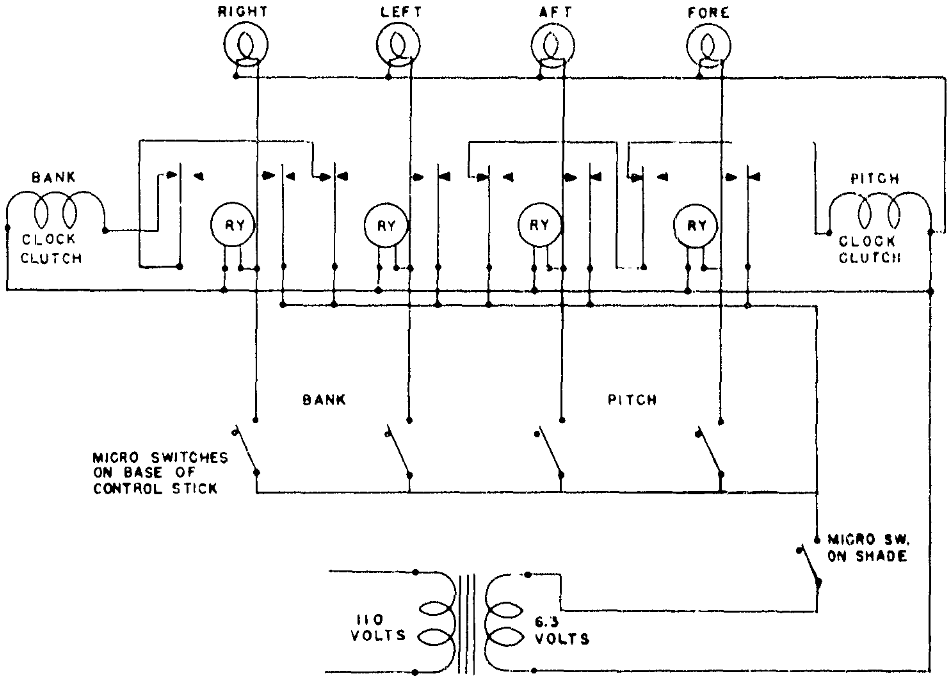



Figure 5: Wiring Diagram of Cockpit Control Stick

TABLE 1

Assignment of Subjects to the Various Experimental Conditions

| | GROUP A (Pilots) | | GROUP B (Novices) | |
|---|---|---|---|---|
| Instrument Type Used | Manual First | Verbal First | Manual First | Verbal First |
| Standard Artificial Horizon (A/H) | 5 | 5 | 5 | 5 |
| Plane Type Presentation (P/T) | 5 | 5 | 5 | 5 |
| Reversed Pitch Stabilized Sphere (RPS/S) | 5 | 5 | 5 | 5 |
| Stabilized Sphere (S/S) | 5 | 5 | 5 | 5 |
| British Type Presentation (BR/T) | 5 | 5 | 5 | 5 |

instrument and the proper method of response. The instructions given the college students (Group B) were necessarily more specific and lengthy in this respect than with the experienced pilots (Group A). When it was felt that the subject had the instructions well in mind he was given three practice trials. At the conclusion of the three practice trials, 21 test trials in each situation, motor and verbal, were presented.

a. Verbal Response Procedure:

For each trial, the attitude indicator was set to a predetermined indication, other than straight and level. The required response was a verbal instruction from the subject indicating the control movement necessary to recover to straight and level flight. In all cases, a response in two dimensions (pitch and bank) was required. These two dimensions were always shown as deviating from the null position.

The words selected for the verbal responses were "up" and "down" for pitch corrections and "left" and "right" for bank corrections. The subject had some latitude in making a response. There was no particular order in which the pitch and bank corrections were given. Either the pitch or the bank correction could be given first, and the order could be changed from trial to trial. The subject could, if he desired, use words other than those suggested for the response. In all cases, however, the subject was urged to use the response words "up - down" and "left - right". In addition to the response words, the subject was asked to follow his response with the word "stick". This was to give the experimenter a positive cue at the completion of a response. The experimenter recorded all errors made by the subject, but did not lower the slide or stop the timer until the correct response was made. This method, in addition to simplifying the analysis of errors, gave the subject knowledge of his performance, even though there was no movement of the indicator.

b. Manual Response Procedure:

As in (a) above, for each trial the attitude indicator was set to an indication other than straight and level. The required response was a movement of the stick in the proper direction to return the plane to a straight and level attitude from the attitude shown on the indicator. There was no actual movement of the cockpit. For the purposes of this study, the magnitude of the response was not taken into consideration. The primary concern was with direction and time. As in (a) above, errors were noted and time was measured to the completion of a correct response. At the completion of each correct response, the subject was asked to recenter his control, which had a distinct centering mechanism.

## III. RESULTS

The data obtained in this experiment consisted of reversal errors and response times. These two measures of performance are presented separately. Wherever possible, the data were examined by means of an analysis of variance.

In the tables and in the discussion, the subgroups are identified by the symbol of the instrument on which they were tested. These symbols are listed in Table 1.

The means for the error data were calculated by dividing the number of errors by the number of subjects and obtaining the percentage value. One hundred per cent equals 21 trials. The means for the response time data were calculated by obtaining a mean for each subject and then calculating a mean for the subgroup or group by dividing the sum of the subject means by the number of subjects. Variance in the response time data is thus the variance of subject means.

Reversal Errors:

Table 2 presents the mean percentage of reversal error frequencies obtained from the pilots and the novices for both aileron (bank) and elevator (pitch) responses for both manual and verbal responses. An analysis of variance indicated there were no reliable differences between subgroups, nor were there any reliable interactions between subgroups and types of response (manual or verbal). However, there were reliable difference between types of response within the main subject groups. Table 3 presents the "t" values for these differences.

When the performance of the two subject groups was compared it was found that there was no interaction between type of response and main subject groups. However, there was a difference in mean number of errors, significant at the 5% level of confidence, between the main subject groups, which favored the pilots.

The data for the several response conditions which are presented in Table 3 show that both the pilots and the novices made less errors on verbal responses than they did on manual responses. However, the differences favoring the verbal responses are more pronounced for the novice subjects than they are for the pilots.

No significant differences were found between the number of aileron (bank) and elevator (pitch) reversals.

Response Times:

The nature of the clock scores precluded an analysis similar to the analysis of reversal errors. Since it was not possible to obtain separate aileron and elevator response times during the verbal portion of the experiment, the data for manual and verbal response times are treated separately.

a. Manual Response Times:

The analysis of the time scores for manual responses indicated that there were no differences between aileron and elevator responses. However, significant differences were found between the main subject groups. No interactions were found between the main subject groups and the subgroups. Reliable differences were found between subgroups within each main subject group.

TABLE 2

Mean Percentage of Errors for Each Subgroup by Response Type (N = 10)
100% = 21 Trials

Group A - Pilots

| Subgroup (Instrument) | Manual Response: Mean % of Aileron Reversals | Manual Response: Mean % of Elevator Reversals | Verbal Response: Mean % of Aileron Reversals | Verbal Response: Mean % of Elevator Reversals | Average Mean % of Reversals |
|---|---|---|---|---|---|
| P/T | 3.33 | 8.09 | 1.43 | .48 | 3.33 |
| A/H | 5.71 | 7.62 | 5.71 | 4.76 | 5.95 |
| BR/T | 10.48 | 13.81 | 3.33 | 4.28 | 7.98 |
| RPS/S | 12.86 | 10.95 | 10.48 | 2.38 | 9.17 |
| S/S | 7.14 | 10.48 | 8.09 | 13.33 | 9.76 |

Group B - Novices

| Subgroup (Instrument) | Manual Response: Mean % of Aileron Reversals | Manual Response: Mean % of Elevator Reversals | Verbal Response: Mean % of Aileron Reversals | Verbal Response: Mean % of Elevator Reversals | Average Mean % of Reversals |
|---|---|---|---|---|---|
| P/T | 13.81 | 15.24 | 9.52 | 5.24 | 10.95 |
| A/H | 12.86 | 9.52 | 8.57 | 4.28 | 8.81 |
| BR/T | 9.52 | 6.19 | 4.28 | 1.90 | 5.48 |
| RPS/S | 11.90 | 9.05 | 7.14 | 3.33 | 7.86 |
| S/S | 21.43 | 19.52 | 11.43 | 6.67 | 14.76 |

Tables 4 and 5 present the means and "t" values for manual response times.

It is noted from Table 4 that the differences in mean manual response times between the main subject groups is reliable at the 1% level of confidence. The pilots have a considerable edge in this instance, whereas the comparison of response errors indicated no differences.

In Table 5 it will be noted that there are considerable differences between the means for the various subgroups. For the pilot groups, the mean manual

TABLE 3

Comparison of Mean Error Frequencies of Verbal and Manual Responses for Each Group and Each Control Dimension (N = 50)

| Group | Control Dimension | Mean Number of Errors Manual | Mean Number of Errors Verbal | "t" | Level of Confidence |
|---|---|---|---|---|---|
| A (Pilots) | Aileron | 1.7 | 1.2 | 1.182 | -- |
| A | Elevator | 2.1 | 1.1 | 2.364 | Beyond 5% |
| B (Novices) | Aileron | 2.9 | 1.7 | 2.837 | Beyond 1% |
| B | Elevator | 2.5 | 0.9 | 3.782 | Beyond 1% |

response times for the P/T, the A/H, and the BR/T subgroups were all significantly superior to the mean for the S/S subgroup at the 1% level of confidence. The mean for the RPS/S subgroup was superior to that of the S/S subgroup at the 5% level. None of the other means differed significantly.

For the novice group, three of the means differed significantly. The mean for the P/T subgroup was superior to that of the S/S subgroup at the 1% level and superior to that of the A/H subgroup at the 5% level. The mean for the BR/T subgroup was superior to that of the S/S subgroup at the 5% level.

b. Verbal Response Times:

An analysis of variance of the response times for the verbal portion of the experiment showed that there were no reliable differences between performance of the main subject groups. Further, there were no reliable interactions between the main subject groups and the subgroups. However, there were considerable differences between subgroups. Because there were no differences between the main subject groups, the data for each instrument in Group A and Group B were combined. Table 6 presents the combined mean verbal response times for each instrument and the "t" values for the mean differences.

TABLE 4

Mean Manual Response Times for Each Group and Significance of Differences

Between Means (N = 50)

| | Mean Manual Response Times | "t" |
|---|---|---|
| Group A - Pilots | 1.396 sec. | 6.897** |
| Group B - Novices | 2.065 sec. | |

** Significant beyond 1% level of confidence.

It will be noted from Table 6 that the mean response times for all instruments were significantly less than the response time for the S/S. Further, the mean response times for the P/T and BR/T instruments were significantly less than the response time for the A/H.

## IV. DISCUSSION OF RESULTS

### Reversal Errors:

The results contained in the error data may be summarized in two statements: (1) the pilots made fewer errors in reacting to the indicators than did the novices, and (2) both groups made fewer errors when they were required to make verbal responses than when they were required to make manual responses.

The first of these statements merely reflects a general principle that a higher level of training is characterized by a smaller number of errors. The second statement is not so predictable. Considering this second result it is noted that the required manual response was a control movement in a different plane than that of the indicator whereas the required verbal response was a statement of the effect of the control movement in the same plane as that of the indicator. There is more difference between these responses than the fact that one is verbal and one is manual.

### Response Times:

The results contained in the response time data may be summarized in three statements: (1) the pilots show shorter response times than do the novices, (2) most of the significant differences in both manual response times and verbal response times involved the inferior performance of the S/S subgroups, and (3) the few remaining significant differences involved the inferior performance of the A/H subgroups, although the performance of these subgroups was not inferior in all comparisons.

The first statement is an expected result. That is, a higher level of training results in greater response speed. The second statement indicates a promising lead for further research. Although individual differences could account for the results, it is considered improbable that both the pilot S/S subgroup and the novice S/S subgroup would contain by chance the individuals with slower response times. It seems more likely that the performance of these subgroups was affected either by a difference in the effectiveness of the instructions or by a difference in the effectiveness of the display. The third statement may be considered in the same way as the second, except that the lack of consistency in this case makes it a somewhat less promising research lead.

### Errors and Response Times:

To obtain a clearer picture of the relationship between the various types of instruments and subject performance in terms of reversal errors and response times, Figures 6 and 7 were drawn. The graphs for these figures were obtained by plotting the mean % of reversal errors against the mean response times for the several conditions of the experiment.

TABLE 5

Mean Manual Response Times for Each Subgroup and Significance of Differences Between Means (N = 10)

| | Mean Manual Response Times (in seconds) | | | | |
|---|---|---|---|---|---|
| | P/T | BR/T | RPS/S | A/H | S/S |
| Group A - Pilots | 1.254 | 1.230 | 1.386 | 1.238 | 1.872 |
| Group B - Novices | 1.719 | 1.904 | 1.986 | 2.307 | 2.408 |

"t" Values

Group A

| | BR/T | RPS/S | A/H | S/S |
|---|---|---|---|---|
| P/T | .111 | .608 | .074 | 2.848** |
| BR/T | | .719 | .037 | 2.959** |
| RPS/S | | | .682 | 2.240* |
| A/H | | | | 2.922** |

Group B

| | BR/T | RPS/S | A/H | S/S |
|---|---|---|---|---|
| P/T | .853 | 1.230 | 2.710* | 3.175** |
| BR/T | | .378 | 1.857 | 2.323* |
| RPS/S | | | 1.479 | 1.945 |
| A/H | | | | .465 |

* Beyond 5% level ** Beyond 1% level

No distinct relationships exist between the number of reversal errors and response times for any main subject group - type of response situation. It will be noted, for example, that in practically every situation considered, the response time for the P/T instrument is less than for any other instrument; however, the reversal errors made on the P/T instrument range from minimum to next to the maximum.

TABLE 6

Mean Verbal Response Times for Combined Main Subject Groups and Significance of Differences Between Means (N = 20)

Mean Verbal Response Times (in seconds)

| P/T | BR/T | RPS/S | A/H | S/S |
|---|---|---|---|---|
| 1.484 | 1.488 | 1.750 | 2.016 | 2.422 |

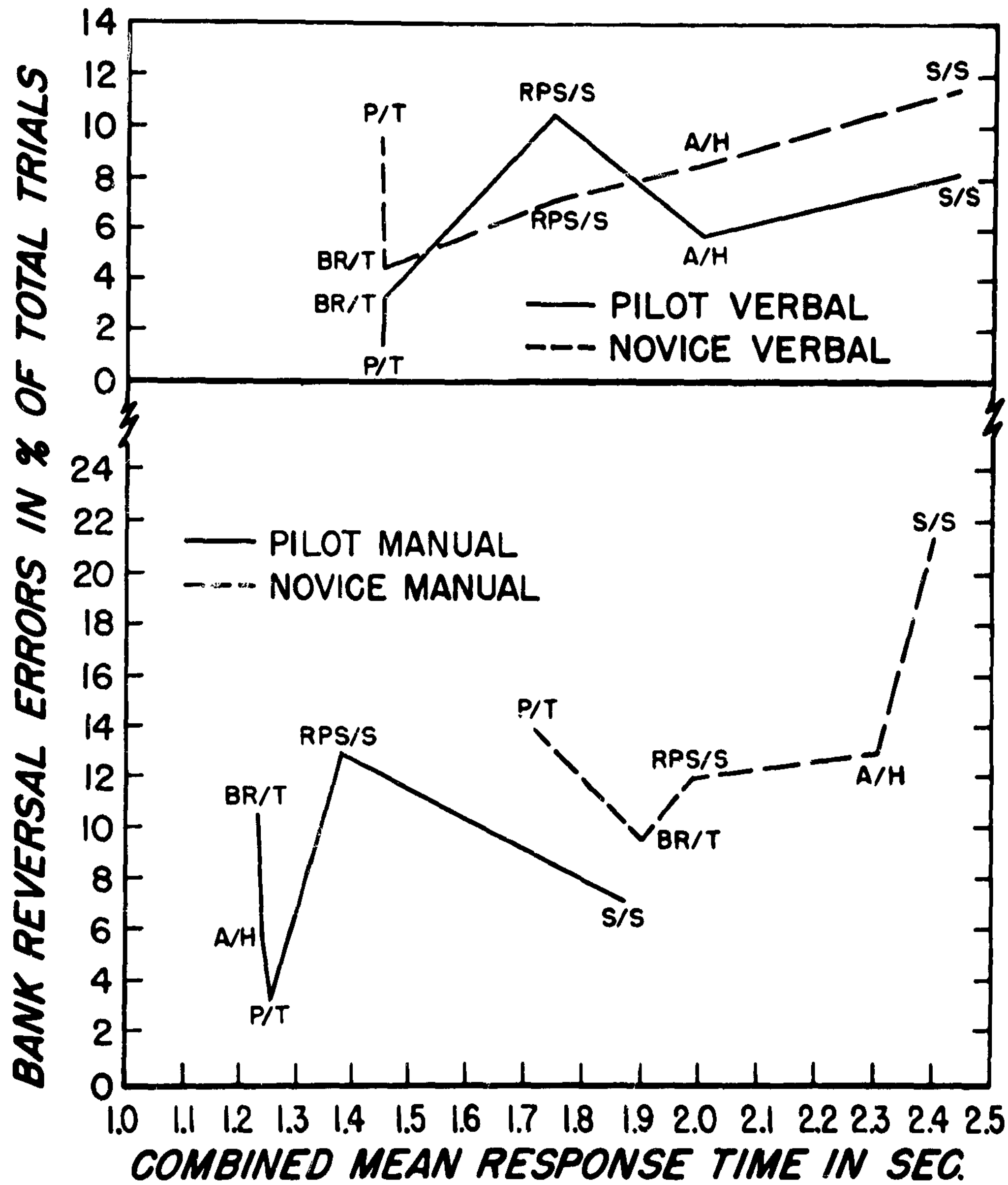
"t" Values

| | BR/T | RPS/S | A/H | S/S |
|---|---|---|---|---|
| P/T | .022 | 1.430 | 2.861* | 5.044** |
| BR/T | | 1.409 | 2.839** | 5.022** |
| RPS/S | | | 1.430 | 3.613** |
| A/H | | | | 2.183* |

* Significant at the 5% level.
** Significant at the 1% level.

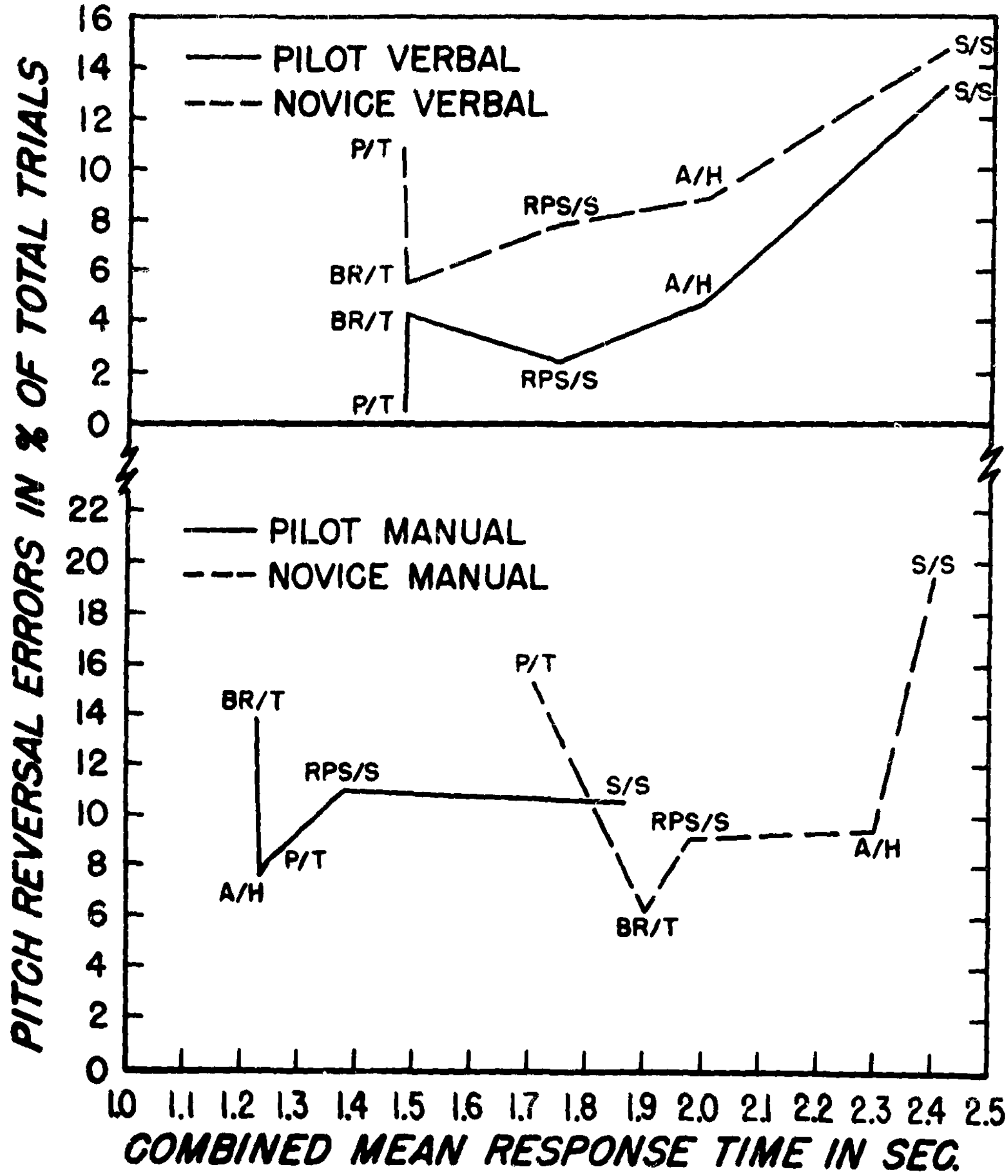
These graphs clearly depict the confusion that exists relative to response times and reversal errors as a measure of performance on attitude indicators.

One further point is worthy of mention. That point is related to performance of the pilots who used the A/H. Despite their considerable experience with this instrument, their errors were not significantly less than those of the pilots who used the several experimental instruments. Each of the ten pilots who used the A/H made 21 manual responses to bank indications and 21 manual responses to pitch indications. Of these 420 responses, 28 or 6.67% were in error. Considering the relatively simple situation in which these responses were obtained and the extent of the familiarity of these pilots with this instrument, this percentage of error is felt to be too large to justify an evaluation of satisfactory performance. Although the results of the present study do not establish an optimal instrument design among those investigated, they do indicate that the Artificial Horizon is not an optimal instrument for attitude indication.




REVERSAL ERRORS VS RESPONSE TIME FOR BANK

FIG. 6




REVERSAL ERRORS VS RESPONSE TIME
FOR PITCH

FIG. 7

## REFERENCES


1. Gardner, John F. An experimental comparison of five different attitude indicators. WADC Technical Report No. 54-32, Wright Air Development Center, April 1954.

2. Browne, R. C. Trial of two attitude indicators. FPRC 611 and 611A, 1945.

3. Loucks, R. B. Evaluation of aircraft indicators on the basis of Link Instrument Ground Trainer performance. 27th Air Force Base Unit, Randolph Field, Texas, Project No. 341.

# APPENDIX I

## Verbatim Instructions for Pilots:

The purpose of this experiment is twofold. First we are attempting to find out which of several methods of presenting attitude or horizon information can be interpreted and reacted to most easily. Secondly, we are making a comparison of verbal versus manual responses to discover whether verbal statements of what the action should be give the same results as actual action on a simulated aircraft stick.

Your work in this experiment will therefore be broken into two parts.

You will be asked to give verbal responses (manual responses) to this instrument during the first period and manual responses (verbal responses) using a stick during the second part.

Altogether, we are comparing five simulated horizon instruments in this experiment, but you will be tested on only one of them.

A. Earth Reference:

This instrument, that you will be using, is one representing the earth reference type. It is the Standard A/H which you have been flying in all Air Force planes and I am sure you understand how it works.

B. Plane Reference:

This instrument, that you will be using, represents one of the plane reference type. The direction of movement of the small airplane is the same as the actual airplane we will assume you are flying, i.e., when the plane moves above the side reference pointer, you are in a climb; when it banks to the left you are in a turn to the left.

Do you have any questions as to how to interpret the instrument?

C. Stabilised Sphere Type:

This instrument, that you will be using, represents the stabilised sphere type. To interpret it properly you must assume this point of view. Consider that the moving element or the sphere of this instrument in this case is a stabilized sphere fixed in reference to the earth and that you are always flying towards it. The miniature plane attached to the instrument case represents your plane, if its left wing is below the mid-horizontal you are turning to the left. If the nose of the miniature airplane is above the mid-horizontal line in the dark area you are approaching the sphere from the top. That is, you are in a dive. If your nose is below the mid-horizontal line in the white, you are approaching the sphere from below and are in a climb.

You will notice that the bank movements are the same as they are with the standard instrument but the pitch movements are reversed.

Do you have any questions as to how the instrument should be interpreted?

D. British or Separate Pitch and Bank Type with Direct Movement Relation:

This instrument that you will be using represents a rather new idea. The bank and pitch information are separated so as to present a rear and side view of your aircraft. The interpretation of this instrument is what you probably would expect. When the nose of the plane in the side view goes up you are in a climb. When the left wing in the rear view goes down you are turning to the left, and so on.

Do you have any questions about the interpretation of this instrument?

E. Sphere Earth Reference Type of Presentation:

This instrument, that you will be using, is different from the standard instrument only in face design. Rather than a bar and moving pointer at the top you have a sphere which represents the earth. There is a mid-horizontal line which serves as a horizon. The bank and pitch relationships are the same as you are accustomed to.

Do you have any questions about the interpretation of this instrument?

Now if you will listen closely I'll explain the proper response procedure.

Verbal:

Notice now that the plane is in a climbing turn to the right--the correct response then during the verbal period would be one that would cause the plane to return to the straight and level position, or left-down stick. In all responses, give verbally the direction of stick movements that would start the plane towards the straight and level position.

The four words we are using for direction of movement during the verbal part of the experiment are right, left, up and down. Remember the response is always one that will start the plane towards straight and level. You may however, give either aileron or elevator movement first, i.e., you may say right-up stick or up-right stick, whichever you prefer; you must make a response to each trial for at no time will both bank and pitch be at the center position.

It is important that you follow each complete verbal response with the word "stick" for it is on hearing this word that the clock is stopped. Once you have ended your response with "stick" no correction you wish to make will be counted; however, if you say "left" and change to "right" before you say the word "stick", your last decision before the word "stick" will be recorded.

I will give you a verbal ready signal before each trial and then pull up the slide; make your response as rapidly and as accurately as possible. There will be about a 4 second delay between each response.

Remember all responses should be in a direction that will start the plane toward straight and level flight.

Do you have any questions?

You will be given four trial responses; after each response you will be told the correct response; however, during the experimental trials you will be given no indication as to whether you made a correct or incorrect response.

Manual:

Notice now that the plane is in a climbing turn to the right-- the correct response would be a stick movement that would start the plane towards the straight and level position. In this case a left-forward stick movement will suffice. You can correct for bank or pitch first or, if you prefer, you can make both corrections at the same time: whichever you prefer. However, you must correct for both dimensions when both are deviating from center.

On some of the trials only one of the dimensions will be off. In such cases, of course, your stick should be moved only in one dimension. There will be no trials when both dimensions are at the center position so every trial should elicit a response. You are asked to make your responses as rapidly and accurately as possible.

I will give you a ready signal before each trial; when you hear it be sure that your hand is on the stick and that your eyes are fixated upon the curtain. As soon as the curtain goes up interpret the instrument and make your response. If you make a wrong response quickly correct it. When you have completed your response the curtain will come down. No correction after the curtain has come down will be scored. Once the curtain is completely down you may center your stick and make ready for the next trial. There will be about 4 seconds between trials.

Do you have any questions?

Instructions for Explaining Instruments to the Novice:

A. Artificial Horizon:

1. Assume that the moving element you see is the horizon, for it will always remain parallel to the horizon of the earth.

2. This in front of it simulates the airplane you are flying; on this instrument it remains stationary.

3. From these, you get an indication of the plane's attitude in relation to the earth's surface -- whether it is climbing, diving, or turning.

4. If the minature plane nose is below the horizon like this, you're diving.

5. If the plane nose is above the horizon like this, you're climbing.

6. If the right wing of the plane is below the horizon like this, you're turning to the right.

7. If the left wing of the plane is below the horison like this, you're turning to the left.

8. Note the little pointer near the top of the instrument. This indicates the degree of bank you have when making a turn. You should consider this point as a cloud out in front of you. When you turn left, this cloud or little pointer moves to the right. And vice versa. Your concern is not with the degree of bank when using the pointer; it is there merely to help you better determine the direction in which you are turning.

9. Here is an example of the instrument combining the two directions as a climb turn.

10. Do you understand?

B. Plane Type:

1. The moving element (the plane) always moves in the direction of your airplane as seen from the rear.

2. Using the side pointers (simulating the horizon) as references, if the right wing of the minature plane is down below that point, you are turning to the right. If the left wing is down, you are turning to the left.

3. If the nose of the minature plane is above the horison, or line connecting the midpoints on either side, the plane is climbing. If the nose is below it, the plane is diving.

C. Reversed Pitch Stabilized Sphere:

1. Imagine that the moving element represents a stabilised sphere out in space which is stationary in relation to the earth. Imagine that you are in an airplane (represented by the miniature one) flying toward it, but never reaching it.

2. The top half of the sphere is white; the lower half is black.

3. When the miniature plane is on the white part, you are flying toward the sky or climbing.

4. When the plane is on the black part, you are flying toward the earth, or diving.

5. Assume that the mid-horizontal line on the sphere is the horizon; when your left wing tips below that line, you are turning to the left. If your right wing drops below the horison line, or any of the parallel lines, you are turning to the right.

6. Here is an example of the instrument showing the plane in a climb turn.

7. Is that clear?

D. British Type Instrument:

1. This presents attitude information on two separate displays.

2. On the left is the information regarding "bank" or turning; on the right is information regarding "pitch", or climbing and diving.

3. When the miniature plane on the left is tilted to the left with its left wing below the midline, you are turning to the left.

4. When the miniature plane's right wing is below the midline and it is tilted to the right, you are turning to the right.

5. When the nose of the plane on the right is up, you're climbing; when it is down, you're diving.

6. Is that clear?

7. Here is an example of the instrument combining the two directions as a climb turn.

E. Stabilized Sphere:

1. Imagine that the moving element represents a stabilised sphere out in space which is stationary in relation to the earth. Imagine that you are in an airplane (represented by the miniature one) flying toward it, but never reaching it.

2. The top half of the sphere is black; the lower half of the sphere is white.

3. When the miniature plane is on the black part, that is when you are flying toward the black part, or earth, you are diving.

4. When the plane is on the white part, that is when you are flying toward the white part or sky, you are climbing.

5. Assume the mid-horizontal line on the sphere is the reference line; when your left wing tips below that line, you are turning to the left. If your right wing drops below the mid-line, or any of the parallel lines, you are turning to the right.

6. Here is an example of the instrument showing the plane in a climb turn.

7. Is that clear?